TOMAS Global Aerosol Microphysics Model

GMI Meeting

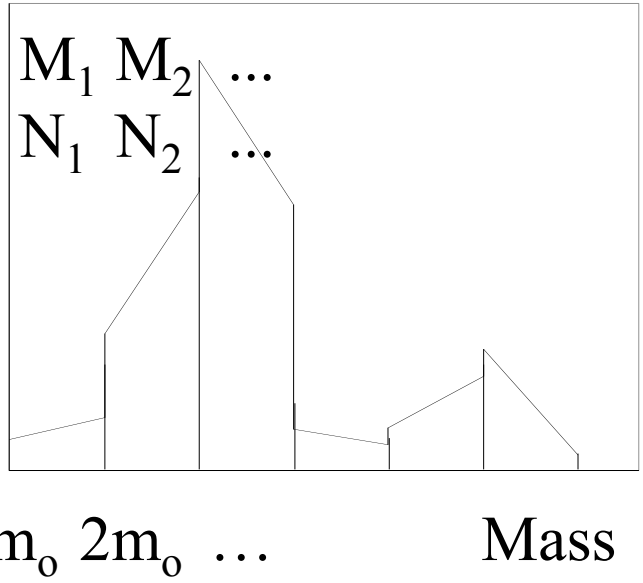
17 November 2004

Overview

- Algorithm Description
- Sample Results
- Status
- Sea-Salt
  - CCN from ultrafine sea-salt
- Carbonaceous Aerosols
  - CCN from EC/OC?
  - Fate of primary ultrafine emissions

TwO-Moment Aerosol Sectional (TOMAS) Model

- Two moments of the size distribution (mass and number) are tracked for each size bin.
- The average size of particles in a given section is not constant with time



- Two-moment method conserves both mass and number precisely
- Prevents numerical diffusion present in single-moment methods
- Excellent size resolution: 30 sections from .01 μm to 10 μm

Aerosol Microphysics

General Dynamic Equation

$$N_k = \int_{m_k}^{m_{k+1}} n_k(m)dm$$

$$M_k = \int_{m_k}^{m_{k+1}} m n_k(m)dm$$

- ~30,000 grid cells
- Adaptive time steps

Coagulation:

$$\frac{dN_k}{dt} = \frac{1}{2}K_{k-1,k-1}N_{k-1}^2 + \psi_{k-1}\sum_{i=1}^{k-2}K_{k-1,i}M_i$$

$$+\frac{\psi_k - f_k}{2x_k}\xi\sum_{i=1}^{k-1}K_{k,i}M_i\overline{m}_i - K_{k,k}N_k^2 - N_k\sum_{i=k+1}^{I}K_{k,i}N_i$$

$$-\frac{\psi_{k-1} - f_{k-1}}{2x_{k-1}}\xi\sum_{i=1}^{k-2}K_{k-1,i}M_i\overline{m}_i - \psi_k\sum_{i=1}^{k-1}K_{k,i}M_i$$

Condensation:

$$M_k(t+\Delta t) = \int_{m_{k,f}}^{m_{k+1,f}}\left[m^{2/3} + \frac{2}{3}\tau\right]^{3/2} n_k(m)dm$$

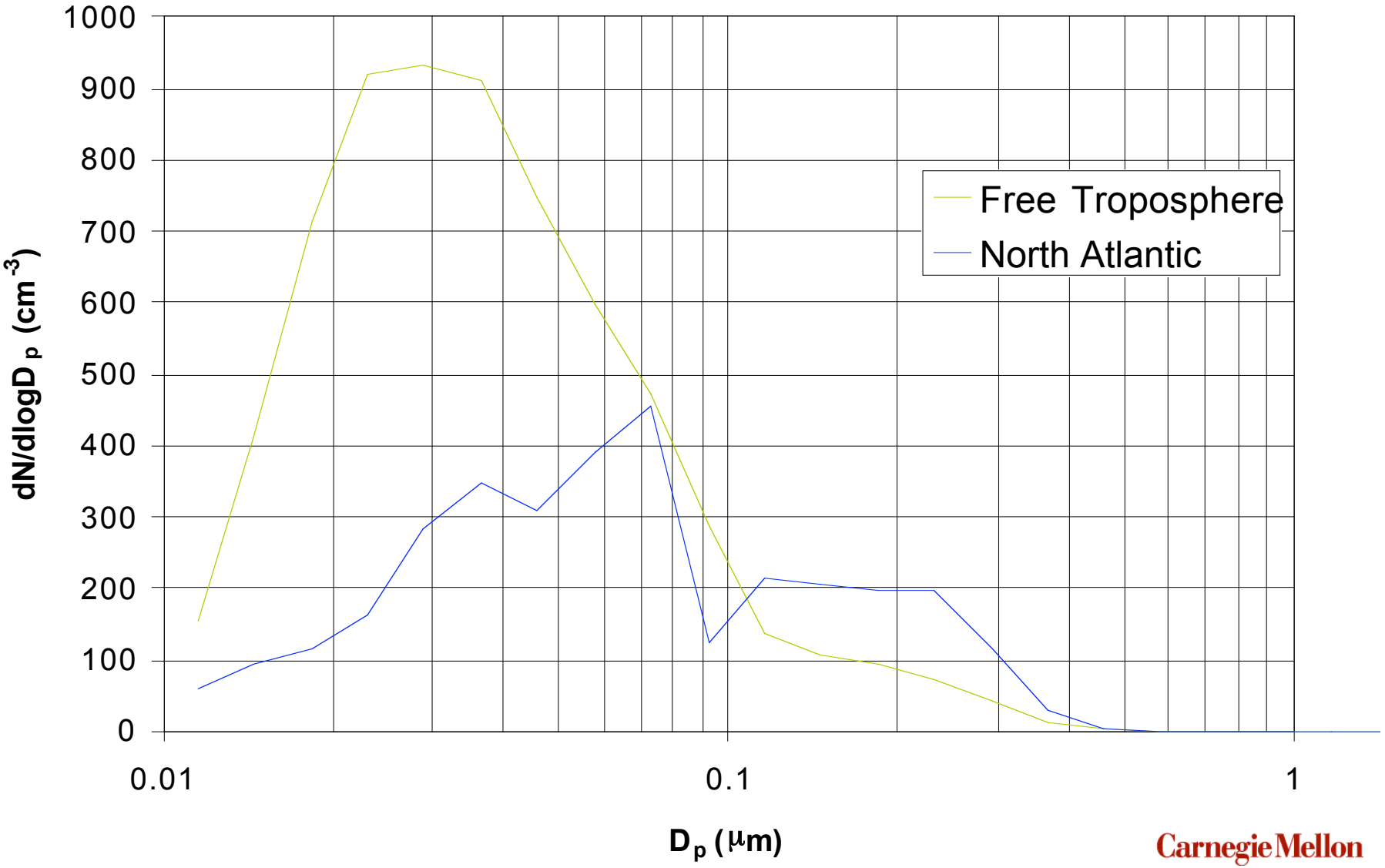
$$m_{k,f} = \left[m_{k,i}^{2/3} - \frac{2}{3}\tau\right]^{3/2}$$

$$\tau = \int_t^{t+\Delta t} C\Delta S(t)dt$$

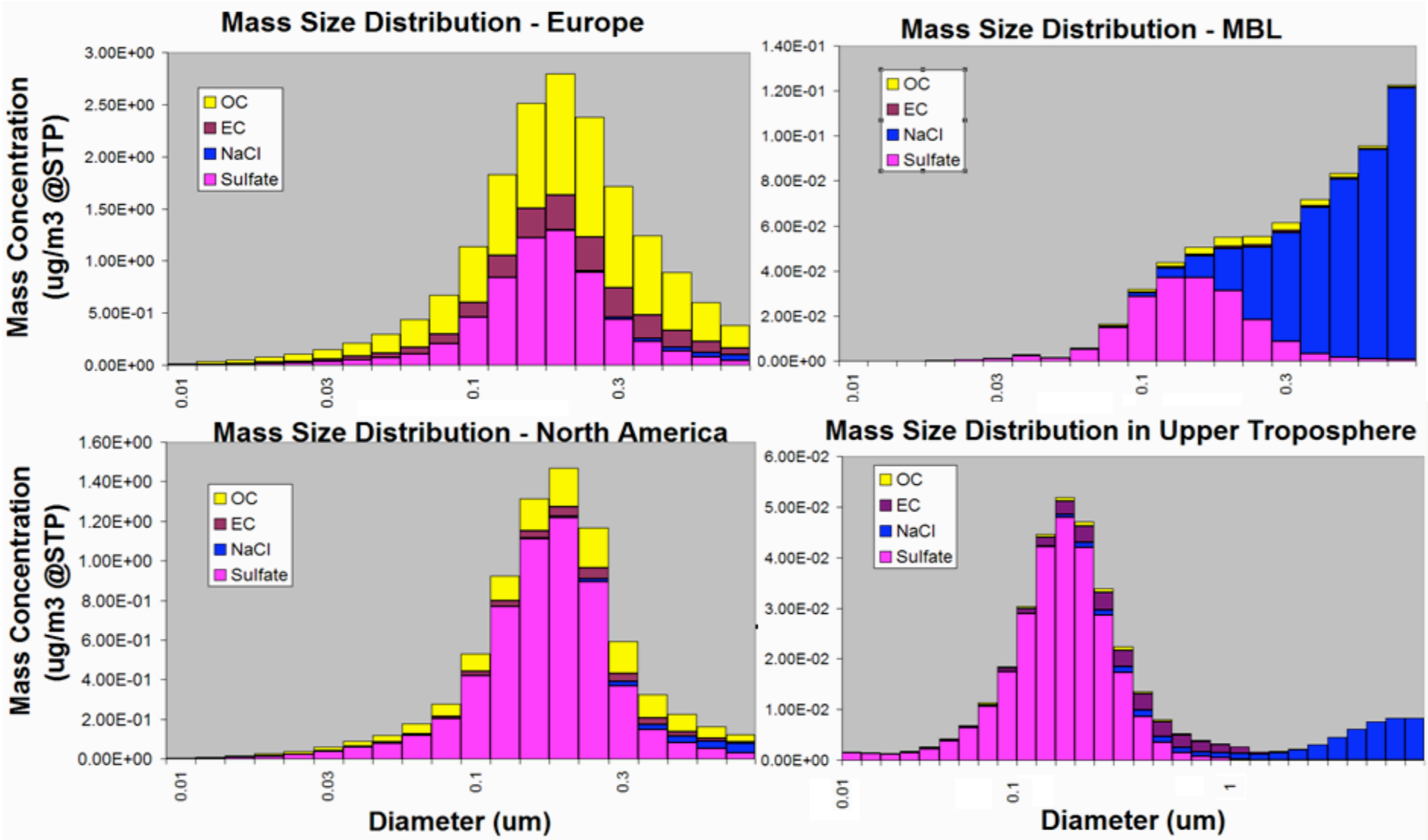
Status and Activities

- Host Models
  - Current: GISS GCM (climate model)
  - In development: GEOS-CHEM (assimilated meteorology)
  - Future: GMI
- Aerosol Types:
  - Published: sulfate
  - Completed: sea-salt, EC, OC
  - Testing: mineral dust

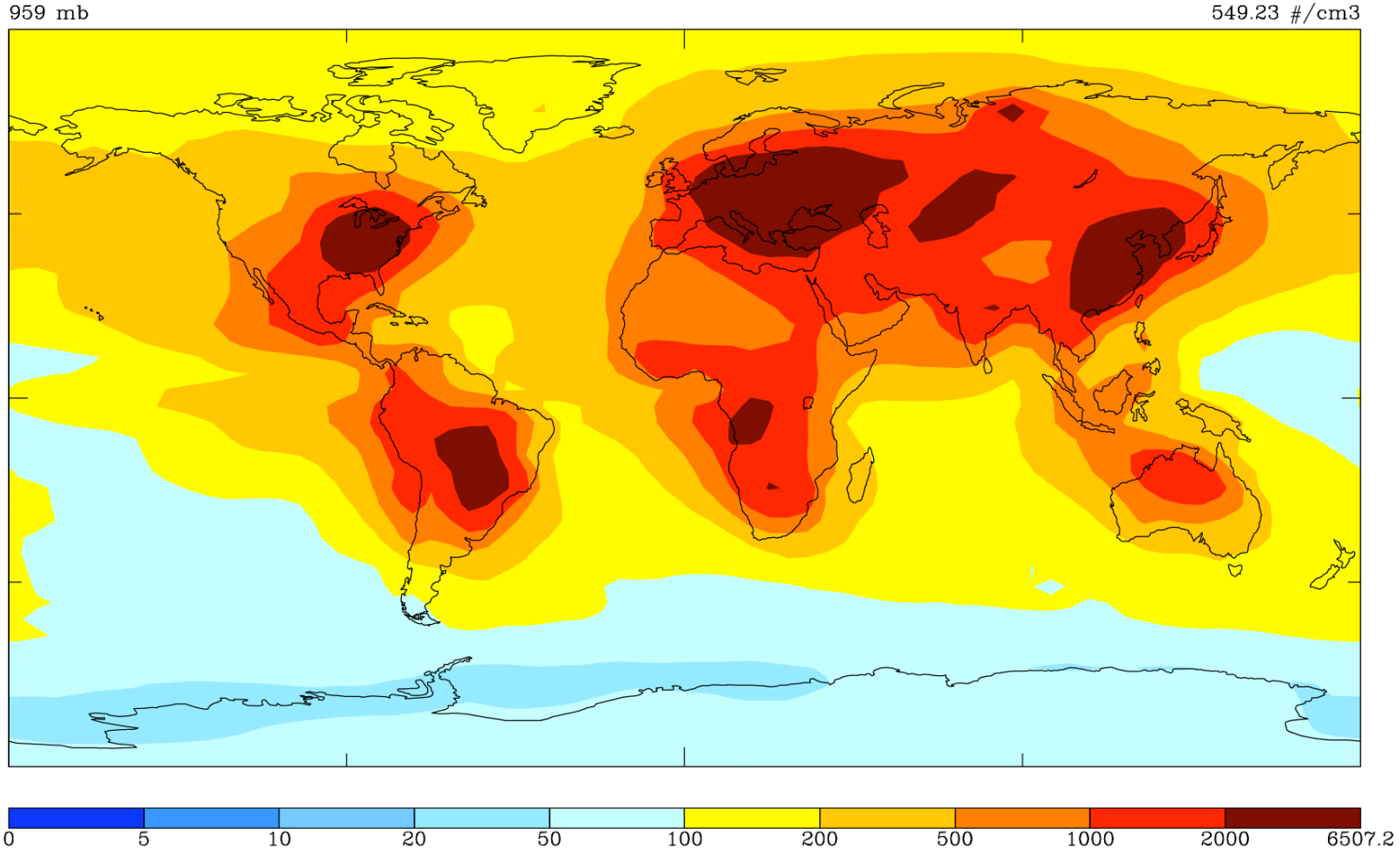
Sample Number Distributions



Sample Mass Distributions



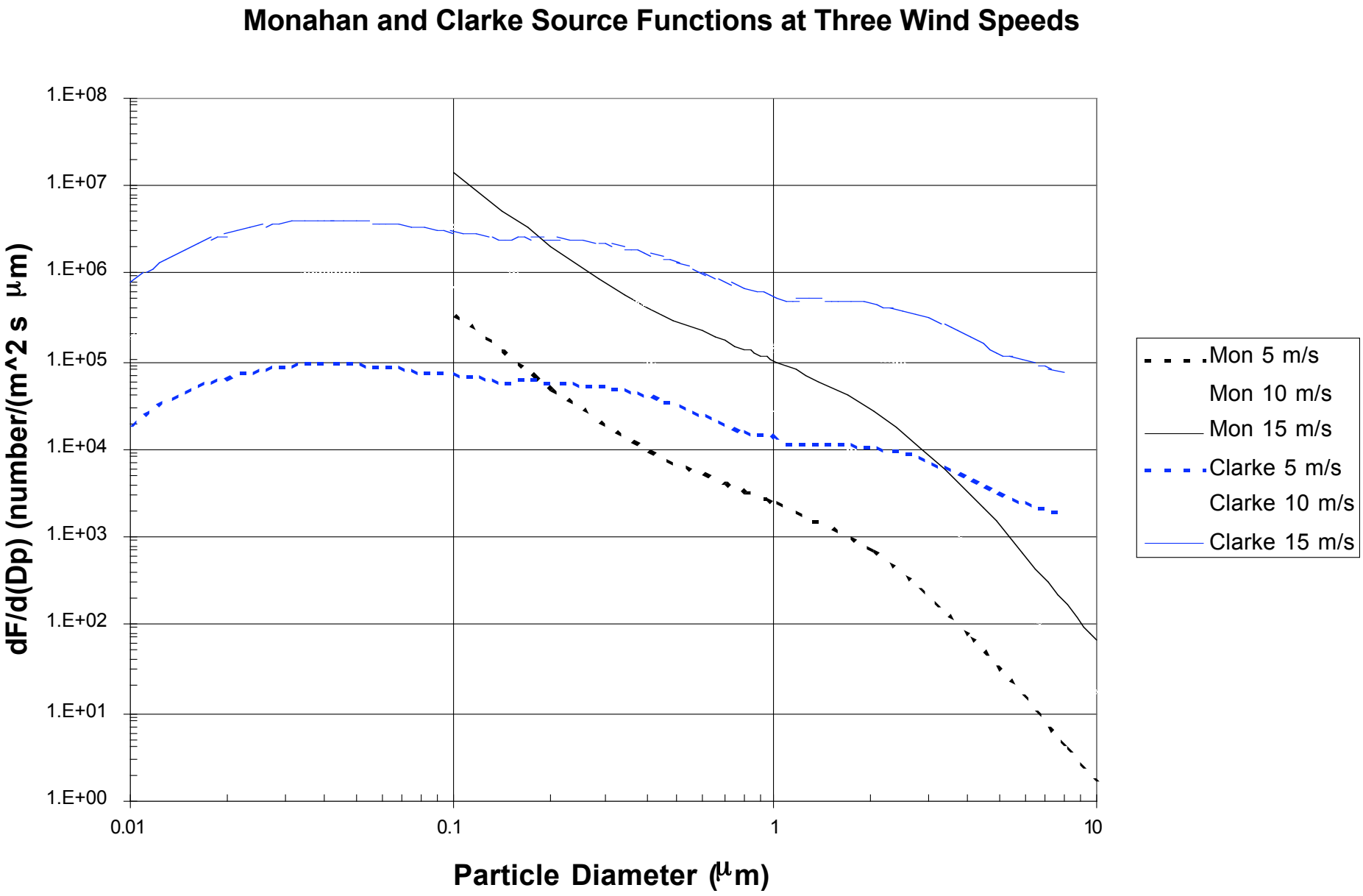
CCN (0.2%) Distribution



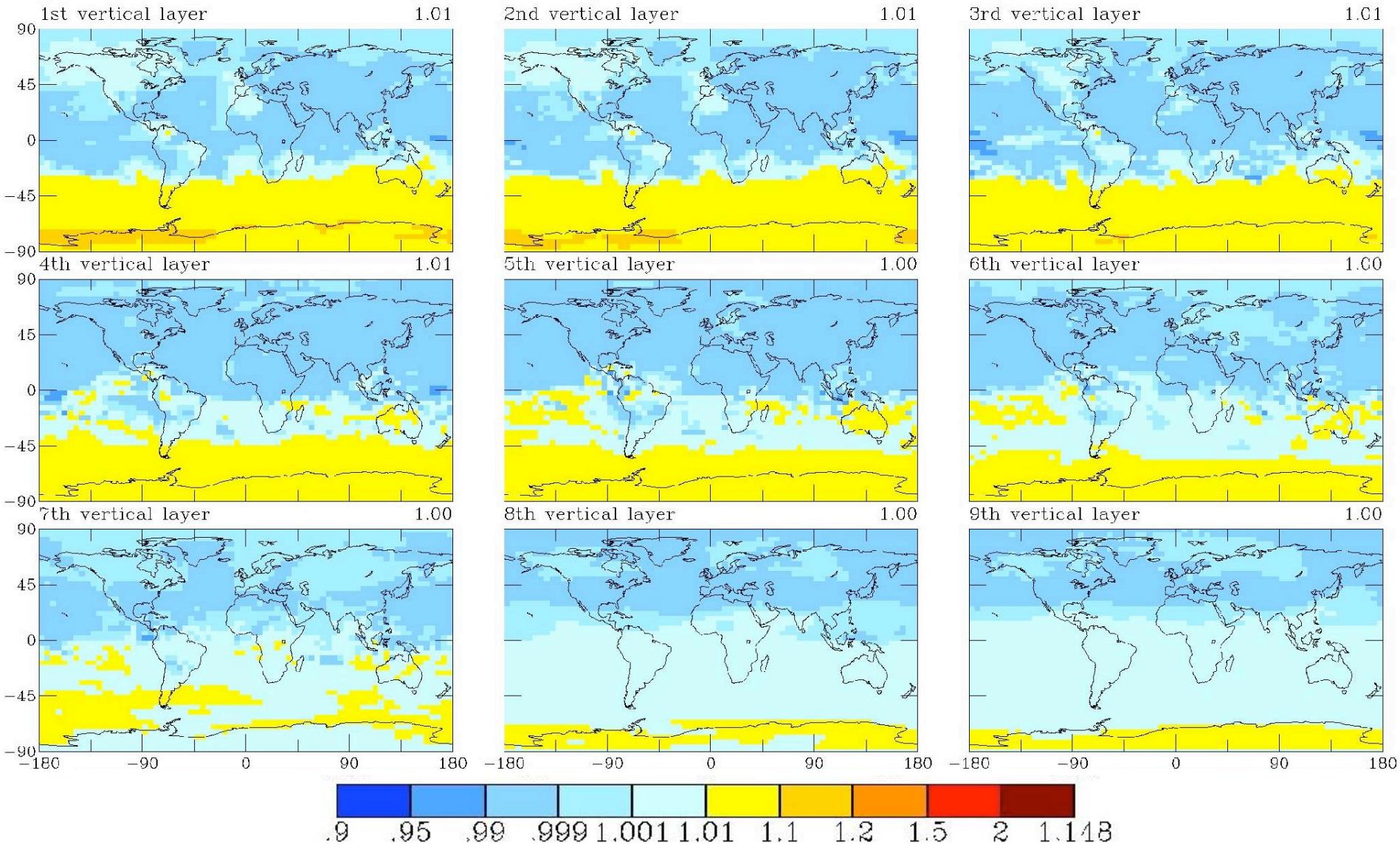
Sea-Salt Emissions

- Issues
  - Size range covered by parameterization: ultrafines (D_p < 100 nm)?
  - Overall uncertainty
- Parameterizations
  - Monahan
    - widely used
    - measured down to 0.4 mm
    - extrapolation to 0.1 mm
  - Clarke: measured ultrafine emissions
  - Also: O'Dowd / Martensson

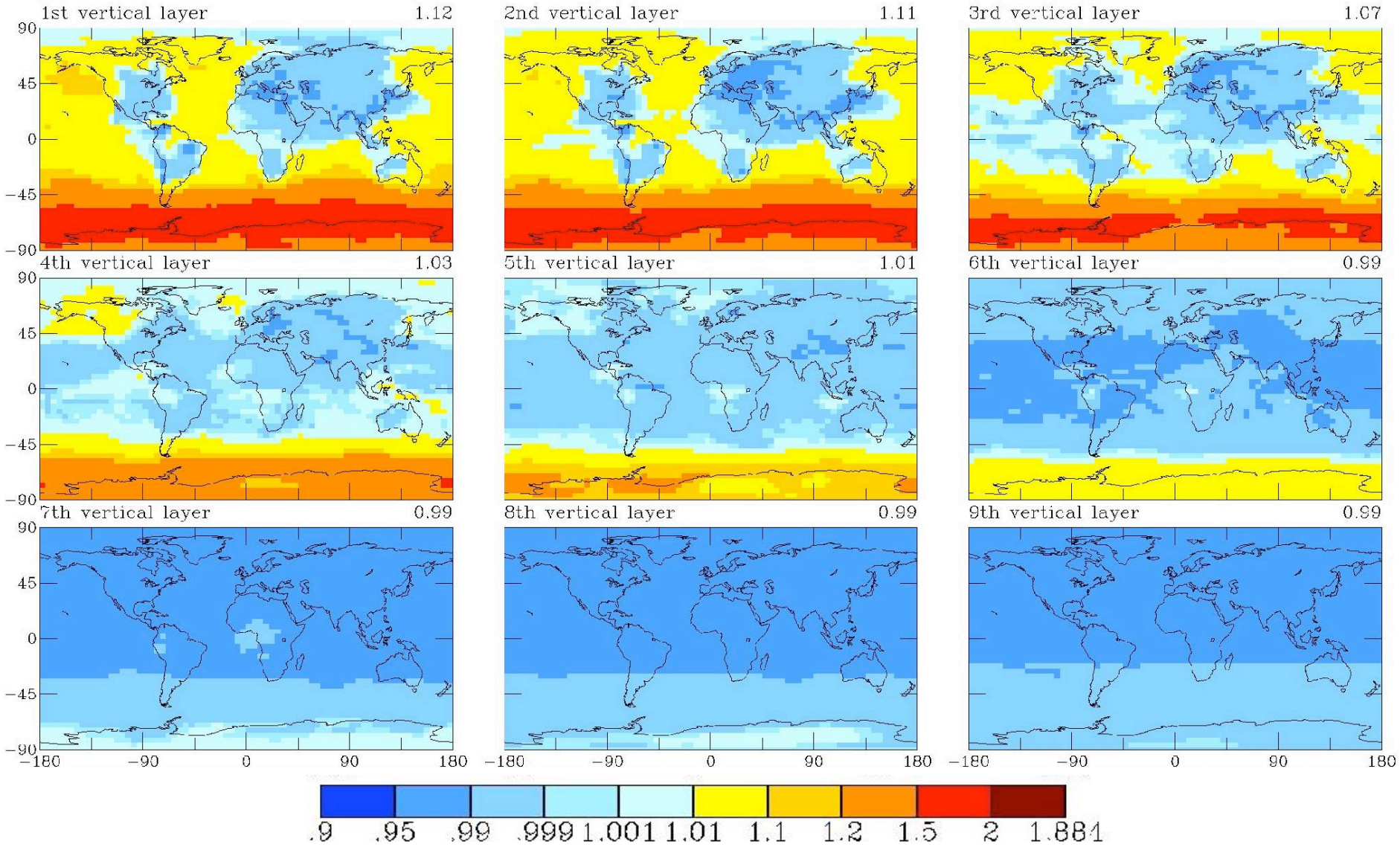
Ultrafine Sea-salt Emissions



Ratio CCN(0.1%) for Clarke with sub 0.1 μm vs. without
March

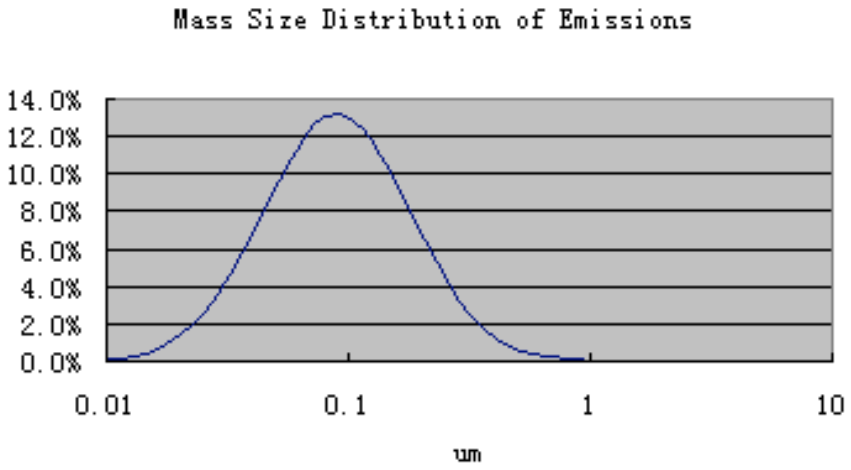


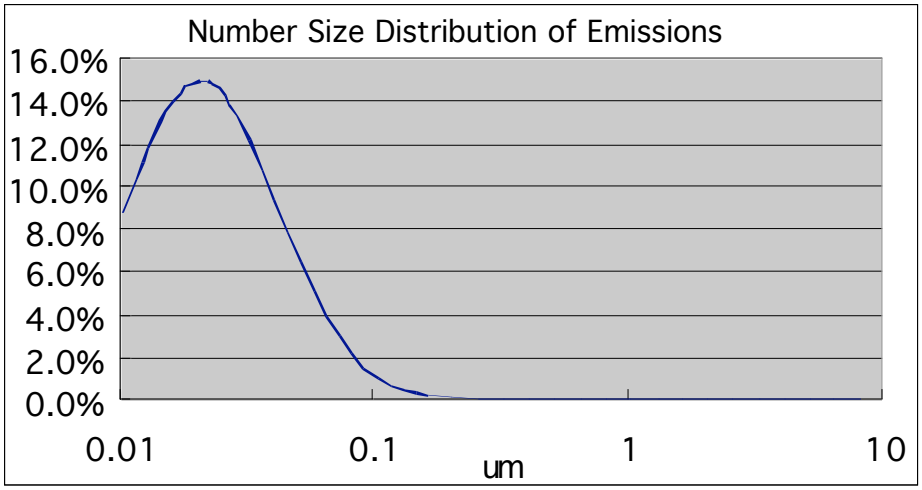
Ratio CCN(0.5%) for Clarke with sub 0.1 μm vs. without
March



EC/OC Emissions in TOMAS Model

- Emission rates are constant in each month
- 80% of BC emitted is assumed to be hydrophobic; while 50% of primary OC is assumed to be hydrophobic [Cooke et al., 1999].
- Assume the size distributions of emissions have a mass mean diameter of 100 nm and GSD of 2 for both BC and OC





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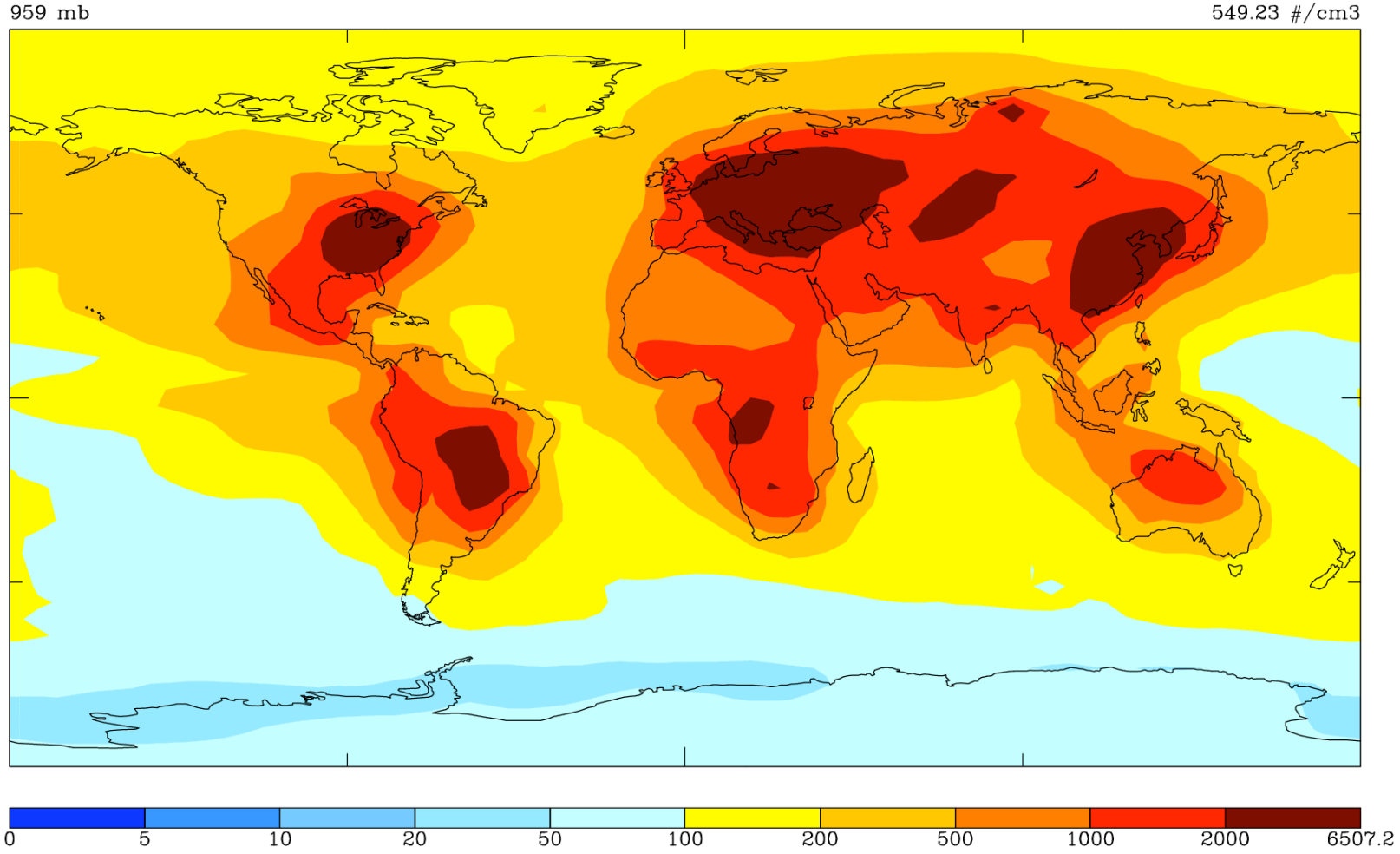
CCN Activity of EC/OC

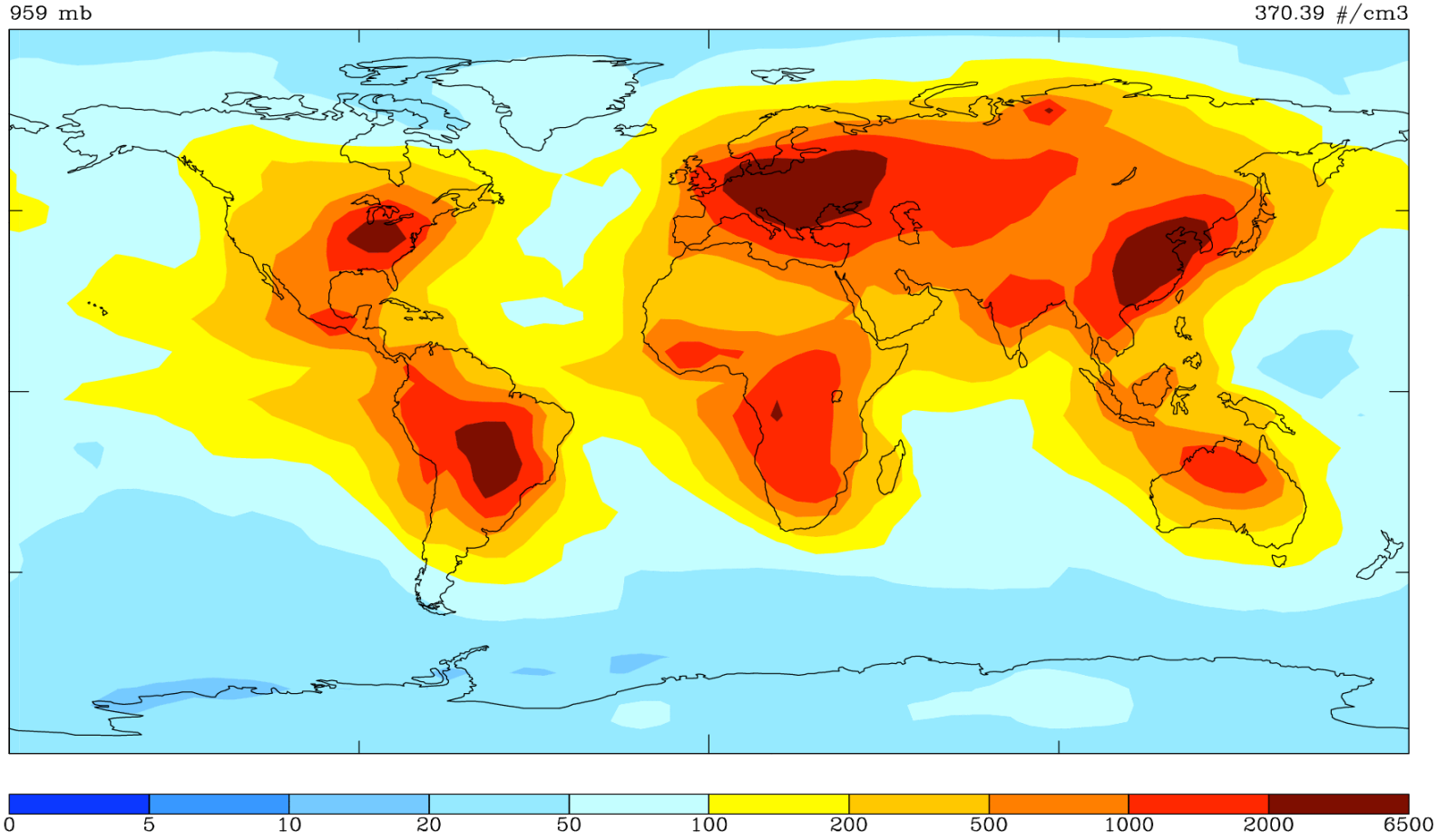
Assume two populations of aerosols:

- Hydrophobic EC is externally mixed from other species.
- All other aerosol species are internally mixed:
  - –Hydrophilic EC (insoluble core)
  - –Hydrophobic OC (slightly soluble, solubility assumed to be 0.009 g per 100 cm^3 H_2O, calculated based on oxalic acid, ¶= pinene, Diesel Fuel, Leucine, Hexadecane, Myristic Acid, Hexadecanol, palmitic acid, stearic acid)
  - –Hydrophilic OC (infinitely soluble, calculated based on Glutamic acid, pinic acid, norpinic acid, gasoline, Glutaric acid, limonene, Adipic acid, cholesterol, Pinonic acid and ¶‡ pinene)
  - –Sulfate and sea-salt

CCN (0.2%) distribution



CCN(0.2%) from Carbonaceous Aerosols



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CCN from Primary Ultrafines

- Assume CCN increase is composed of direct emissions of accumulation mode particles and growth of ultrafine particles.

$$\Delta CCN_{carbo} = \Delta CCN_{accumulation} + \Delta CCN_{ultrafine}$$

$$\Delta CCN_{accumulation} = \sum R_i(\frac{\#}{m^2 s}) \times A_{earth} \times \tau_i, i \in EC/OC$$

$$\Delta CCN_{ultrafine} = \Delta CCN_{carbo} - \Delta CCN_{accumulation}$$

- Half of "EC/OC CCN" are direct emissions of accumulation mode particles
- Other half are growth of ultrafine EC/OC emissions to CCN sizes